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Quantitative Monitoring of Ammonia and Hydrazines: Absolute Cross Sections for Electron Impact Ionization

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13. ABSTRACT (*Maximum 200 words*)

Absolute cross sections are reported for electron impact dissociative ionization of ammonia, hydrazine, and monomethyl hydrazine. Electron energies were varied from the ionization thresholds to 260 eV. The measurements were made using a pulsed electron-molecule crossed beam apparatus equipped with a time-of-flight mass spectrometer. These data will assist in quantitative analysis for air sampling or other monitoring applications that use mass spectrometry.

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Hydrazines are used extensively as a propellant fuel for launch vehicles (Titan) and satellite maneuvering. They are also toxic and carcinogenic, and as such pose a potential health hazard to those involved in manufacture, handling, transport, and fueling. Accidental releases also pose environmental risks and, if they occur during transport, risks to the public.[1] Electron impact mass spectrometry is a commonly used analytical tool for measuring the contents of a gaseous sample. Applications range from atmospheric monitoring to laboratory research. In all cases, quantitative measurements require accurate cross sections for ionization. We present here a tabulation of the electron impact cross sections for ionization and dissociative ionization for NH_3, N_2H_4, and monomethyl hydrazine (MMH) under jet-cooled conditions. These data were obtained as part of a larger study on the ionization and spectroscopic properties of hydrazines reported in the *Journal of Chemical Physics*.[2,3] One should refer to those papers for details on the experimental measurements. Here we simply present the numerical values of the ionization cross sections that were not previously published. Molecules at ambient temperatures undergo more fragmentation upon ionization and, therefore, will have a distribution of partial cross sections that shifts toward smaller fragment ions. We are currently measuring this effect.

Electron-impact and photoionization measurements of hydrazines are very limited. Recently, we reported a comprehensive study on EI dissociative ioniation cross sections, fragment appearance potentials, and fragment kinetic energies as a function of electron energy for jet-cooled NH_3, N_2H_4, and MMH.[2,3] Other than this work, we are not aware of any cross-section measurements (either total or partial) for any hydrazine molecule. Berkowitz measured PI thresholds for the formation of $N_2H_3^+$ and $N_2H_2^+$ fragments from N_2H_4.[4,5] Foner and Hudson measured EI thresholds for $N_2H_2^+$ formation.[6] Besides our work, no threshold measurements for MMH dissociative ionization are available other than a very early photoionization[7] and electron-impact[8] study limited to larger fragments.

Much more information is known about NH_3 ionization. There are currently large discrepancies in the electron-impact data in terms of absolute cross sections and threshold potentials for dissociative ionization. The most reliable EI cross-section measurements are currently those by Bederski, Wójcik, and Adamczyk (BWA),[9] Märk, Egger, and Cheret (MEC),[10] and Crowe and McConkey (CM).[11] Accurate fragment-ion threshold curves for EI ionization of NH_3 have been recorded by Morrison and Traeger[12] and by Locht *et al.*[13] The latter group also recorded KE distributions as a function of electron energy.[13] Although a consensus of data is beginning to emerge for some measurements, there still exists significant uncertainties in many of the reported cross sections and threshold potentials, particularly for weak and energetic species. We compare our cross section and threshold potentials for NH_3 to these previous studies. Satisfactory agreement is obtained in most cases, and discrepancies are usually explainable by differing instrument detection efficiencies for fragments with high kinetic energy.

The total ionization cross section for NH_3, N_2H_4, and MMH is plotted in Fig. 1. The

partial cross sections for individual parent and fragment ions are presented as follows:

NH_3: Fig. 2 and Table I.
N_2H_4: Fig. 3 and Tables II and III.
MMH: Fig. 4 and Tables IV-VII.

The reported cross sections in Tables I-VII do not take into account the drop in detection efficiency for highly energetic ions. The fragment kinetic energies measured in Ref. 3 are summarized in Fig. 5 and the detection efficiency of each ion is reported by the righthand scale. The partial cross sections of energetic ions need to be corrected for detection efficiency. The total cross sections in Fig. 1 are only slightly affected because the total ion signal is dominated by ions of low kinetic energy.

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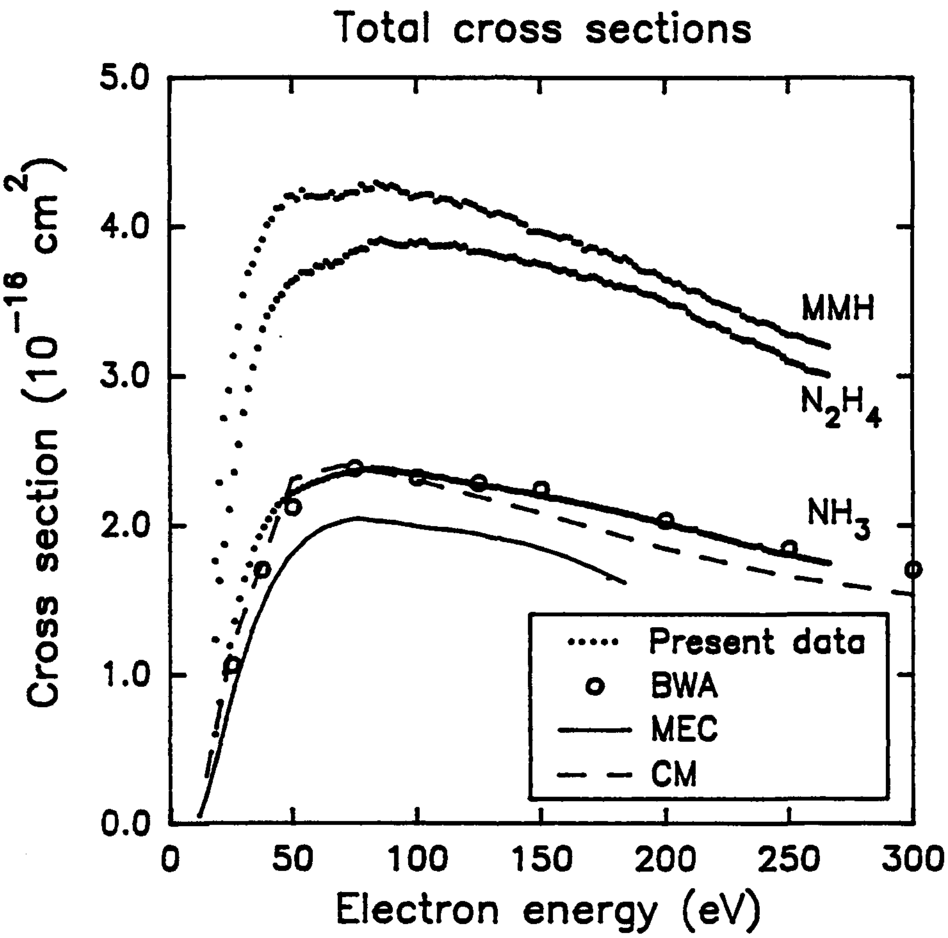

Figure 1. Total EI cross sections for NH_3, N_2H_4, and MMH as a function of electron energy. The NH_3 data of BWA (Ref. 9), MEC (Ref. 10), and CM (Ref. 11 are included for comparison.

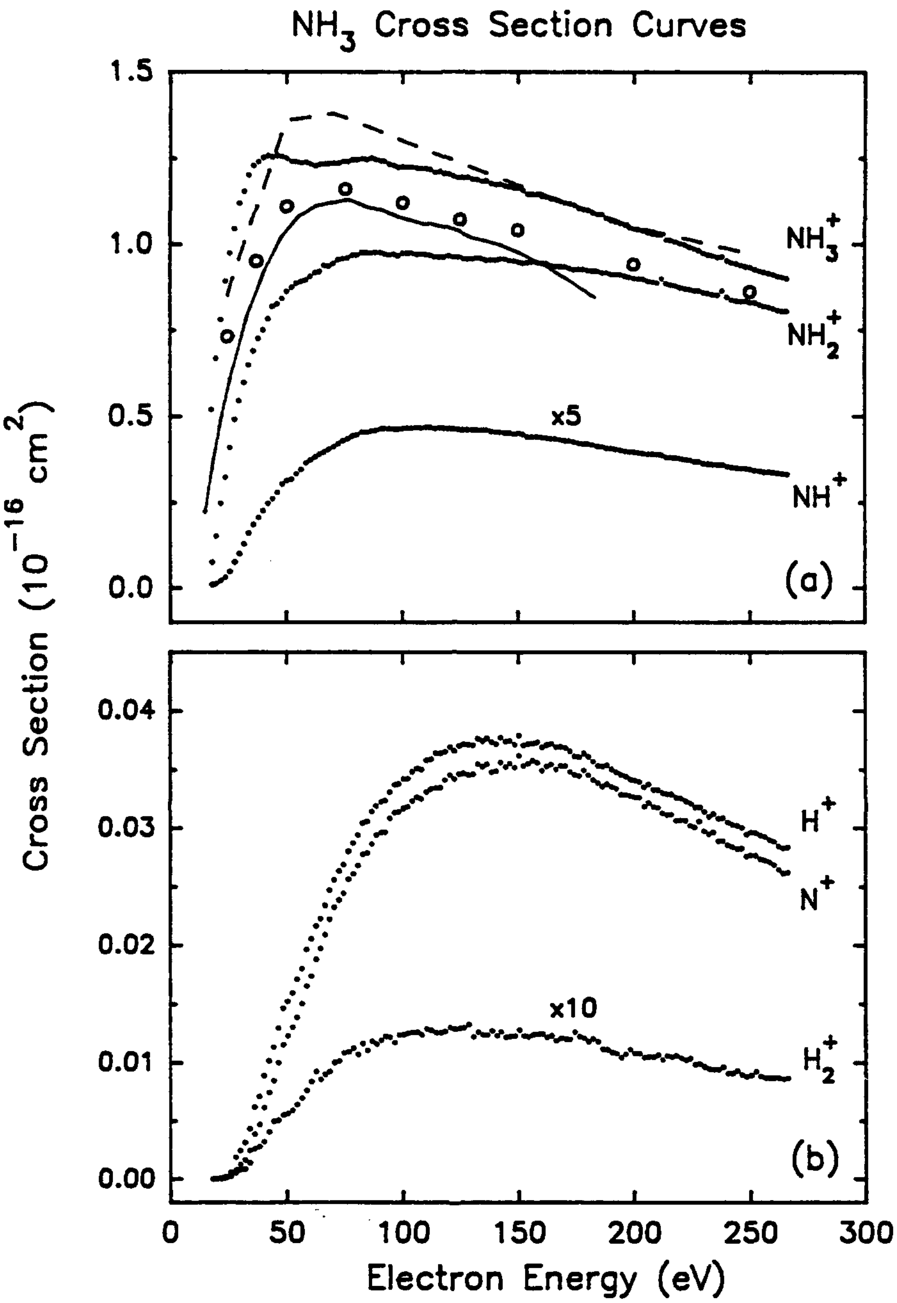

Figure 2. Partial dissociative ionization cross sections for NH_3 as a function of electron energy. NH_3^+ data from other studies are given above and identified in the legends and caption to Fig. 1.

TABLE I. Partial dissociative ionization cross sections for NH_3.

E (eV)	σ (10^{-18} cm^2)					
	NH_3^+	NH_2^+	NH^+	H^+	H_2^+	N^+
16						
18	51.4	7.42	0.2	0.00518	0	0
20	67.2	15.3	0.278	0	0.000369	0
22	79.4	25.2	0.469	0.0136	0.000147	0.00355
24	91.2	33.2	0.677	0.0294	0.00176	0.0103
26	99.9	42.2	1.02	0.0654	0.0027	0.0241
28	108	50.5	1.6	0.197	0.00579	0.0822
30	115	56.2	2.11	0.255	0.00868	0.129
32	118	61.3	2.68	0.324	0.00919	0.171
34	123	66.5	3.32	0.446	0.0145	0.253
36	125	70.4	3.83	0.633	0.0267	0.393
38	126	73.7	4.21	0.721	0.0287	0.475
40	126	75.8	4.59	0.898	0.0328	0.619
42	127	79	5	1.02	0.0409	0.747
44	126	82.2	5.25	1.14	0.0497	0.846
46	126	82.5	5.6	1.29	0.0505	0.996
48	125	83.8	6.07	1.46	0.0547	1.15
50	124	85.6	6.25	1.51	0.0559	1.22
52	122	86.4	6.31	1.57	0.0584	1.28
54	122	87.5	6.59	1.69	0.0631	1.37
56	121	87.8	6.83	1.77	0.0685	1.48
58	122	88.2	7.19	1.93	0.0747	1.62
60	121	89	7.36	2.02	0.0821	1.71
62	120	90	7.52	2.13	0.0908	1.84
64	121	90.5	7.7	2.19	0.0838	1.94
66	121	92.4	7.83	2.3	0.0884	2.06
68	121	91.9	7.98	2.43	0.0911	2.18
70	122	93.1	8.15	2.52	0.0986	2.29
72	122	94.3	8.34	2.6	0.1	2.36
74	123	94.7	8.51	2.66	0.107	2.42
76	123	95	8.64	2.77	0.108	2.54
78	124	96.1	8.82	2.85	0.112	2.59
80	124	96.3	8.9	2.92	0.106	2.66
82	125	97.3	9.08	3.03	0.116	2.77
84	124	97.2	9.07	3.05	0.11	2.78
86	125	97.3	9.16	3.14	0.118	2.86
88	125	97.7	9.2	3.19	0.116	2.94
90	124	97.8	9.32	3.23	0.119	2.97
92	124	97.3	9.33	3.24	0.123	2.97
94	123	97	9.32	3.32	0.122	3.09
96	123	97.6	9.3	3.38	0.117	3.14
98	123	96.7	9.28	3.39	0.124	3.15

100	123	98.1	9.4	3.45	0.125	3.19
104	124	98.4	9.45	3.52	0.127	3.27
108	124	98.2	9.47	3.54	0.125	3.29
112	124	98.2	9.54	3.65	0.129	3.39
116	123	97.9	9.55	3.7	0.128	3.4
120	123	98.5	9.48	3.77	0.133	3.52
124	122	98.1	9.41	3.78	0.132	3.53
128	122	97.9	9.47	3.8	0.136	3.53
132	122	98.6	9.45	3.86	0.129	3.64
136	122	97.8	9.46	3.87	0.127	3.65
140	121	97.9	9.33	3.82	0.126	3.59
144	120	98.7	9.31	3.85	0.125	3.63
148	120	98	9.24	3.83	0.127	3.62
152	119	97.4	9.23	3.82	0.126	3.64
156	118	98.1	9.11	3.85	0.128	3.7
160	118	97.6	9.07	3.81	0.129	3.61
164	117	97	8.99	3.85	0.127	3.67
168	117	96.8	8.93	3.83	0.125	3.66
172	116	96.4	8.89	3.79	0.124	3.61
176	115	96.3	8.76	3.74	0.126	3.57
180	114	95.8	8.74	3.74	0.122	3.58
184	113	95.7	8.58	3.67	0.122	3.52
188	112	95.3	8.45	3.68	0.115	3.51
192	111	94.7	8.39	3.61	0.111	3.46
196	110	94.3	8.3	3.58	0.111	3.42
200	109	93.7	8.24	3.54	0.112	3.39
204	108	93.6	8.16	3.49	0.108	3.31
208	107	92.7	8.13	3.47	0.109	3.31
212	107	94.3	8.11	3.45	0.107	3.27
216	105	91.9	7.94	3.43	0.109	3.25
220	105	91.2	7.87	3.39	0.108	3.2
224	104	90.7	7.78	3.35	0.108	3.15
228	103	90.5	7.7	3.32	0.103	3.2
232	101	89.4	7.56	3.23	0.0984	3.07
236	100	89	7.49	3.22	0.098	3.02
240	99.4	88.4	7.41	3.19	0.0943	2.98
244	98.5	87.2	7.31	3.15	0.0972	2.94
248	97.6	87.3	7.28	3.08	0.0912	2.88
252	96.8	86.8	7.17	3.09	0.0967	2.89
256	95.9	85.5	7.05	3.05	0.0903	2.84
260	95.1	84.7	7.02	3.01	0.0906	2.8
264	94.3	83.8	6.94	2.94	0.0889	2.72

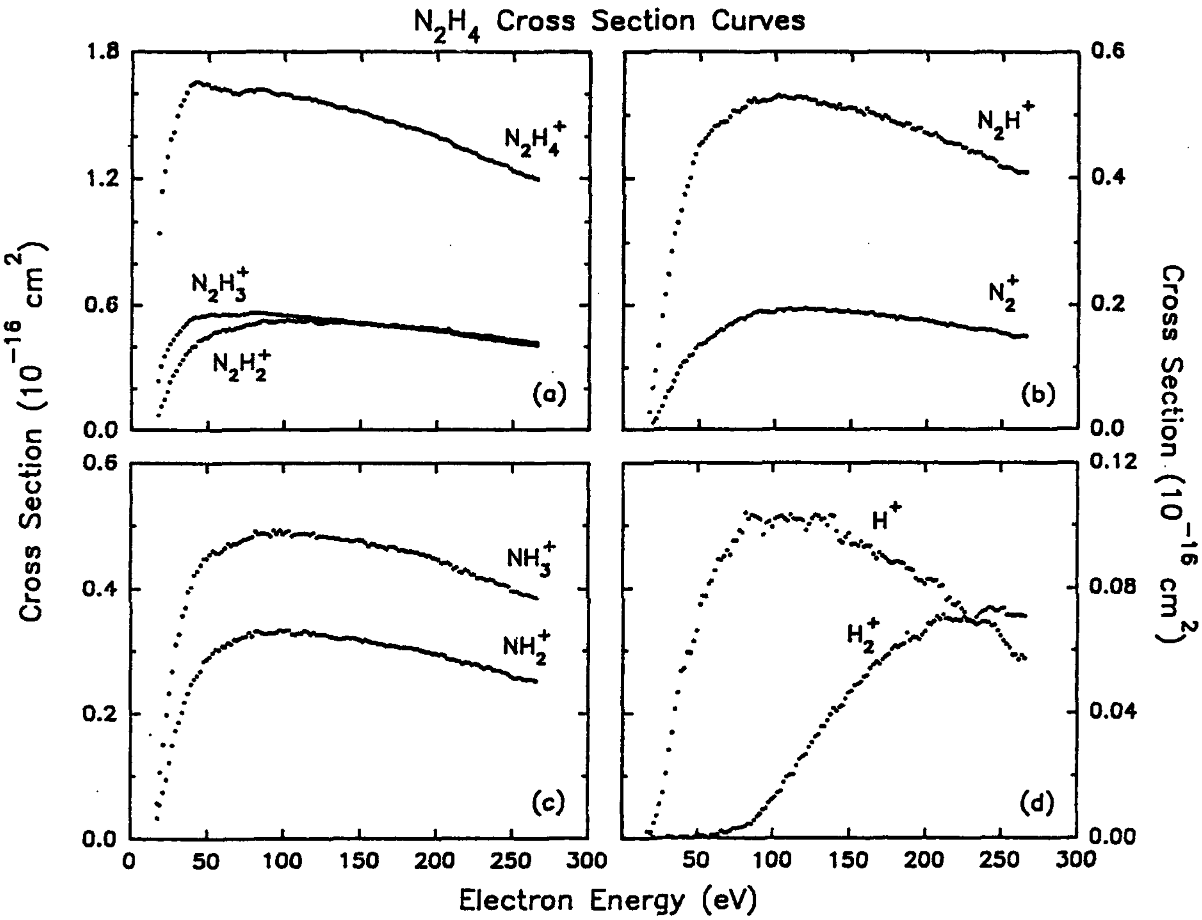

Figure 3. Partial dissociative ionization cross sections for N_2H_4 as a function of electron energy.

TABLE II. Partial dissociative ionization cross sections for N_2H_4; masses 28–32.

E (eV)	σ (10^{-18} cm^2)				
	$N_2H_4^+$	$N_2H_3^+$	$N_2H_2^+$	N_2H^+	N_2^+
16					
18	93.5	23.1	6.72	2.81	
20	115	31	11.5	6.8	1.11
22	125	36.2	14.8	9.56	1.72
24	133	39.6	19	13.7	2.78
26	142	42.4	23.8	18.7	3.8
28	146	44.9	27.3	22.2	5.24
30	154	47.4	29.5	25.6	6.28
32	158	49	32.6	29.2	6.79
34	161	51	34.8	32.1	7.92
36	164	52.4	37.4	33.8	9.11
38	167	53.8	38.8	35.5	10.2
40	167	54.4	40.4	37.8	10.9
42	167	54.9	40.7	39	11
44	166	54.6	43	40.1	11.8
46	164	54.9	43.3	42.2	12
48	164	54.5	44.2	43.5	13
50	163	55	44.1	44.8	13.5
52	161	55	45.2	45.1	13.6
54	161	55	46.5	45.6	13.7
56	160	54.3	46.5	46.1	14.2
58	159	54.1	46.7	46.7	14.5
60	159	54.4	47.5	47.3	14.8
62	159	54.2	46.5	47.4	15.3
64	158	54.4	47.8	48	15.8
66	157	54.3	47	48	15.6
68	157	54.4	48	48.1	16.3
70	157	54	48.5	49	16.7
72	159	54.7	49	50	16.7
74	160	55.1	49.6	49.9	17.2
76	160	55.3	50.3	49.9	17.5
78	160	55.8	49.8	50.7	17.7
80	160	56	50.6	51	17.6
82	162	56.1	50.9	52.1	18.2
84	161	56.1	51.5	51.8	18.3
86	162	56.4	52.5	52.6	18.8
88	162	56	52.3	52	18.9
90	161	55.7	51.6	52	19.1
92	160	55.7	51.7	52.4	18.8
94	160	55.5	51.5	52.2	18.9
96	160	55.4	52.3	52.4	18.7

98	161	55.3	52.8	52.6	18.8
100	161	55.2	52.3	53.1	18.9
104	161	55.6	53.1	53.3	19.4
108	160	55.1	52.7	53.3	19.5
112	160	55.3	52.9	53.2	19.4
116	161	55.4	53.4	53.7	19.6
120	161	54.8	52.6	53.8	19.9
124	159	54.1	52.2	53.3	19.6
128	159	54.2	52.8	52.8	19.6
132	158	54.1	52.5	53.3	19.8
136	157	53.8	52.6	52.7	19.4
140	157	53.6	53.2	52.4	19.7
144	156	53.1	52.8	52.4	19.4
148	157	53.2	52.3	52.8	19.7
152	156	53	52.4	52.6	19.4
156	155	52.6	52.3	52.2	19.3
160	154	52.4	52.3	52.8	19.2
164	153	52.2	52.2	52	19.4
168	152	51.7	51.2	51.6	18.9
172	152	51.6	52.4	51.7	19
176	150	51.2	51.2	50.8	18.8
180	149	50.8	51	50.4	18.3
184	149	50.5	51.2	50.1	18.6
188	149	50.2	51	50.5	18.4
192	147	49.9	50.8	49.6	18.3
196	147	49.7	50.7	49.8	18.5
200	145	49.1	50.4	49	18.2
204	144	48.8	49.7	48.9	18.1
208	143	48.8	50.5	48.5	17.7
212	141	47.8	48.7	47.9	17.7
216	140	47.2	47.8	47.6	17.8
220	139	46.8	47.6	47.4	17.3
224	138	46.5	47.7	46.8	17.2
228	136	45.8	47.3	46.1	16.9
232	135	45.6	46.9	46	16.8
236	134	45.2	47.1	46	16.8
240	133	44.9	46.1	45	16.6
244	132	44.4	45.9	45	16.5
248	130	43.7	45.3	43.7	16.2
252	128	43.4	45.2	43.6	16
256	127	42.9	44.7	43.3	15.6
260	126	42.6	43.8	42.7	15.6
264	125	42.4	43.3	42.8	15.8

TABLE III. Partial dissociative ionization cross sections for N_2H_4; masses 1–17.

E (eV)	σ (10^{-18} cm^2)			
	NH_3^+	NH_2^+	H_2^+	H^+
16				
18	5.61	3.21		
20	10.7	5.47		0.198
22	15.3	7.55		0.522
24	20.3	9.62		0.761
26	23.9	12.4		1.12
28	27.5	15.3		1.49
30	32	17.8		2.12
32	33.5	19		2.87
34	36.5	20.7		3.45
36	37.7	22.2		4.2
38	40.1	23.6		4.71
40	40.7	24.9		5.37
42	42.5	25.6		5.44
44	43	26.1		5.94
46	43.7	26.7		5.88
48	44.6	28.1		6.25
50	44.4	28.4		6.56
52	44.9	28.7		7.37
54	45.4	29.3		7.63
56	44.9	29.7		7.59
58	44.8	29.5		7.99
60	45.2	30.3		8.09
62	45.5	30	0.0785	8.4
64	46.3	30.7	0.119	8.75
66	45.9	30.5	0.233	8.74
68	46.3	31.3	0.175	8.86
70	46.3	31.1	0.179	9.06
72	46.8	31.6	0.237	8.92
74	47.2	31.8	0.315	9.39
76	47.3	32	0.319	9.4
78	47.7	32.7	0.337	9.75
80	47.8	32	0.35	9.68
82	48.9	32.9	0.384	10.4
84	48.4	33	0.472	10.2
86	48.7	32.7	0.448	10.3
88	48.7	32.6	0.585	10.3
90	48.6	32.7	0.711	10.2
92	48.3	32.7	0.794	10.2
94	49.3	32.8	0.929	9.7
96	48.8	33	0.966	10.1

98	49.4	33.4	1.14	10.2
100	48.9	33.3	1.24	9.99
104	49.6	33.6	1.47	10.4
108	49.2	32.9	1.81	10.3
112	49.4	33.2	2.05	10.5
116	49.4	33.5	2.35	10.3
120	49.7	33.5	2.64	10.3
124	49.3	33.2	2.96	10.2
128	49.3	33.2	3.3	10.6
132	49.3	32.9	3.65	10.4
136	49.1	32.6	3.86	10.2
140	48.9	32.8	4.27	10.6
144	48.9	32.9	4.31	9.78
148	49.2	32.8	4.58	9.92
152	49	32.3	4.83	9.67
156	48.2	32.4	5.08	9.65
160	48.5	32.3	5.33	9.61
164	48.4	32.1	5.61	9.64
168	47.9	31.7	5.82	9.24
172	48.3	31.8	5.9	9.33
176	47.6	31.5	6.08	9.15
180	47.7	31.6	6.37	9.16
184	47.7	31.5	6.39	9.12
188	47.4	31.5	6.81	8.95
192	47.1	31	6.67	8.89
196	47	30.8	6.58	8.54
200	46.5	30.8	6.87	8.44
204	45.8	30.5	7.1	8.63
208	46	29.8	7.38	8.6
212	45.1	29.8	7.48	8.47
216	44.5	29.4	7.3	8.03
220	45	29.4	7.28	7.75
224	44	28.9	7.24	7.65
228	43.5	28.9	7.29	7.25
232	43.4	28.3	7.23	7.19
236	43.3	28.5	7.51	7.18
240	42.6	27.9	7.61	7.19
244	42.4	27.7	7.67	7.07
248	42.1	27.3	7.57	6.9
252	41.3	26.6	7.7	6.57
256	40.9	26.8	7.44	6.32
260	40.7	26.3	7.42	6.11
264	40.2	26.3	7.41	6.09

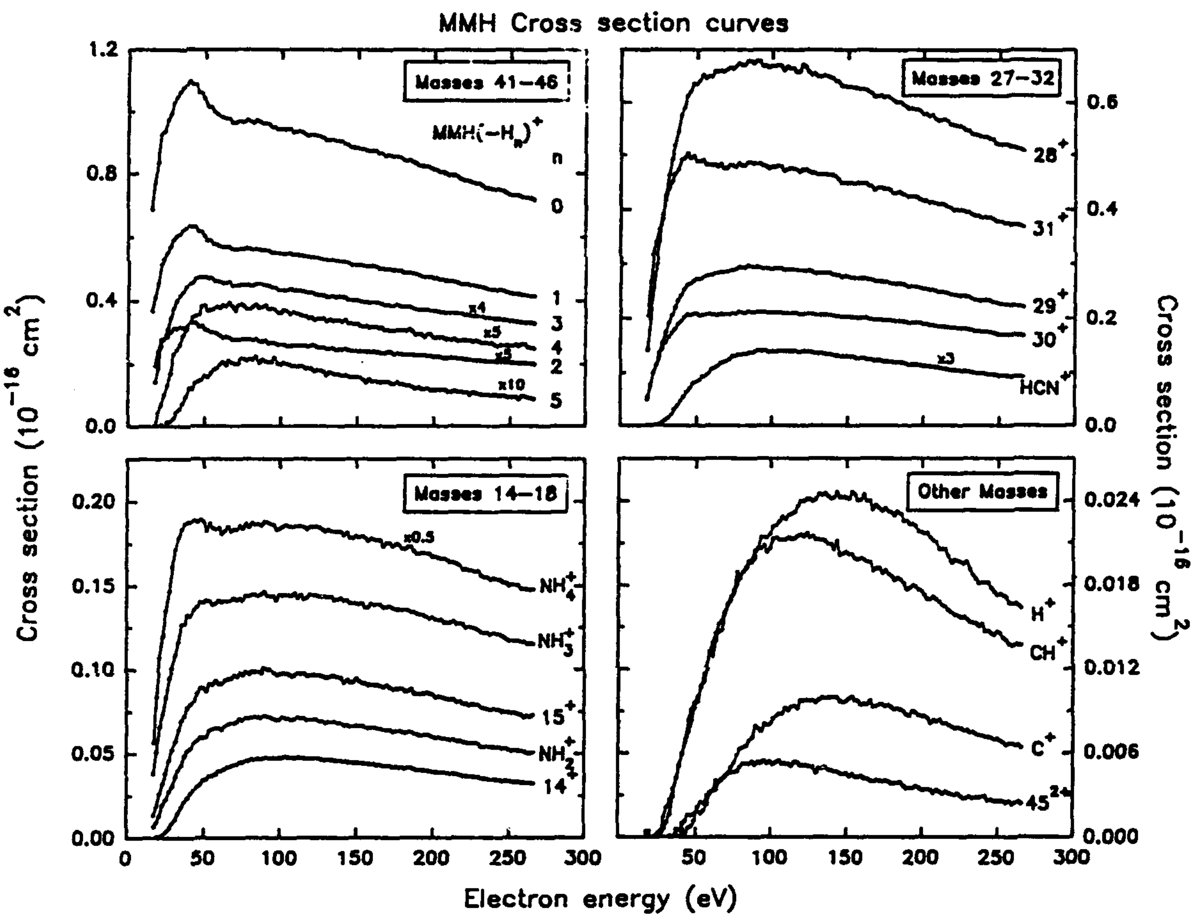

Figure 4. Partial dissociative ionization cross sections for MMH as a function of electron energy. $MMH(-H_n)^+$ designates loss of n H atoms

TABLE IV. Partial dissociative ionization cross sections for MMH; masses 41–46.

E (eV)	σ (10^{-18} cm^2)					
	MMH$^+$	MMH(-H)$^{+\ a}$	MMH(-2H)$^+$	MMH(-3H)$^+$	MMH(-4H)$^+$	MMH(-5H)$^+$
16						
18	69.4	36.8	3.88	3.51		
20	85	46.2	4.89	4.76	0.853	
22	95.3	53	5.69	6.54	1.36	
24	97.3	55.4	5.85	7.24	2.09	
26	102	57.8	6.03	8.18	2.75	
28	106	60.4	6.38	9.19	3.61	0.169
30	110	63.6	6.73	10.1	4.94	0.285
32	114	65.5	6.71	10.9	5.3	0.486
34	114	65.4	6.78	11.2	5.58	0.585
36	114	65.8	6.61	11.3	6.14	0.758
38	113	65.5	6.62	11.6	6.42	0.976
40	113	65.1	6.71	11.5	6.71	1.26
42	110	63.9	6.67	11.5	7.04	1.16
44	109	63.4	6.56	11.8	7.04	1.37
46	106	61.8	6.33	11.9	7.09	1.44
48	106	61.4	6.38	11.8	7.63	1.48
50	104	60	6.13	11.8	7.68	1.61
52	101	58.6	6.04	11.7	7.29	1.55
54	101	58.7	5.93	11.7	7.39	1.69
56	99.6	57.6	5.98	11.5	7.46	1.82
58	98.9	57.5	5.85	11.4	7.59	1.87
60	98.1	56.8	5.72	11.4	7.47	1.97
62	97.8	56.6	5.59	11.3	7.68	2.05
64	97.4	56.6	5.7	11.3	7.58	1.93
66	97.3	56.7	5.61	11.4	7.85	2.09
68	95.9	56	5.48	11.1	7.58	2
70	96.1	55.8	5.49	11.1	7.3	1.96
72	96.5	56	5.53	11.2	7.69	2
74	96.2	55.9	5.49	11.2	7.75	2.15
76	96.2	56	5.5	11.2	7.57	2.14
78	97.1	56.5	5.49	11.2	7.4	2.07
80	96.4	56	5.54	11.1	7.42	2.14
82	95.9	55.7	5.45	11.2	7.6	2.11
84	97	56.3	5.56	11.3	7.75	2.22
86	96.3	55.9	5.36	11.3	7.47	2.01
88	95.7	55.6	5.37	11.1	7.56	2.12
90	95.7	55.6	5.45	11.1	7.68	2.04
92	95.5	55.5	5.24	11.1	7.39	2.03
94	94.5	54.9	5.31	10.9	7.46	2.03
96	94.4	54.8	5.26	11	7.37	2.19
98	93.7	54.7	5.18	10.7	7.18	1.99

100	94.1	54.6	5.17	10.8	7.18	1.95
104	94	54.5	5.08	10.8	7.27	1.97
108	92.7	54.1	5.14	10.7	7.22	1.88
112	93.2	54.1	5.1	10.7	7.05	1.9
116	92.1	53.7	5.1	10.6	7	1.83
120	92.2	53.4	5.18	10.6	6.88	1.83
124	91.7	53.3	5.03	10.4	6.84	1.8
128	91	52.8	5.01	10.4	6.84	1.74
132	90.4	52.4	4.93	10.3	6.78	1.74
136	90.1	52.3	4.86	10.2	6.7	1.64
140	89.8	52.1	4.92	10.3	6.61	1.61
144	88.8	51.6	4.83	9.98	6.5	1.57
148	87.9	51.2	4.74	9.93	6.45	1.54
152	87.4	51	4.76	9.87	6.32	1.53
156	87	50.6	4.73	9.86	6.38	1.37
160	87	50.6	4.73	9.84	6.33	1.41
164	86.1	49.8	4.68	9.78	6.2	1.38
168	85.2	49.6	4.64	9.57	6.06	1.41
172	85.3	49.5	4.74	9.52	6.03	1.35
176	85	49.1	4.65	9.64	6.06	1.4
180	83.9	48.5	4.53	9.45	6.09	1.31
184	84	48.6	4.59	9.47	6.17	1.3
188	82.9	48.1	4.5	9.24	5.79	1.17
192	82	47.2	4.51	9.21	5.79	1.16
196	81.9	47.4	4.48	9.22	5.87	1.22
200	81	46.8	4.41	9.09	5.59	1.13
204	80.2	46.3	4.41	9.05	5.67	1.14
208	79.7	46	4.37	8.93	5.53	1.16
212	79.4	45.8	4.37	8.95	5.44	1.08
216	78.7	45.3	4.3	8.92	5.39	1.08
220	77.7	44.8	4.26	8.8	5.5	1.06
224	77.3	44.6	4.22	8.71	5.41	0.989
228	76.7	44.2	4.15	8.68	5.44	1.04
232	75.9	43.9	4.16	8.67	5.24	0.981
236	75.3	43.3	4.13	8.6	5.25	0.995
240	74.9	43	4.1	8.48	5.13	0.999
244	74.5	42.9	4.05	8.39	5.13	0.934
248	73.5	42.3	4.06	8.36	5.17	0.91
252	72.9	41.9	4.02	8.31	5.1	0.936
256	72.9	41.8	4	8.21	5.06	0.836
260	72.3	41.5	4	8.18	5.2	0.947
264	72	41.1	3.98	8.16	4.96	0.875

[a] Notation indicates number of H atoms lost.

TABLE V. Partial dissociative ionization cross sections for MMH; masses 27-31.

E (eV)	σ (10^{-18} cm^2)				
	31 amu	30 amu	29 amu	28 amu	27 amu
16					
18	20.5	5.4	4.9	14.3	0.0214
20	27.2	7.81	7.31	20.2	0.0035
22	32.6	10.4	10.1	26.2	0.0463
24	35.4	12	11.8	31.1	0.0556
26	38.3	13.5	14.4	35.7	0.0979
28	41.5	15.2	16.5	40.6	0.221
30	44.7	16.6	18.6	45.7	0.39
32	47.5	17.9	20.7	50.2	0.549
34	48.4	18.6	22.1	52.8	0.759
36	49.1	19	23.2	54.7	1.06
38	49.1	19.6	24.2	56.5	1.31
40	50.3	19.9	24.7	59	1.57
42	50.1	20.5	25.6	59.9	1.82
44	50.5	20.8	26.3	61.6	2.11
46	49.4	20.5	26.4	62.3	2.34
48	49.7	20.8	26.8	63.5	2.65
50	48.7	20.8	27.2	63.4	2.73
52	48.6	20.3	27	64.1	2.83
54	48.9	20.6	27.5	65.2	3.1
56	48.1	20.6	27.7	64.5	3.11
58	48	20.7	27.8	65	3.26
60	48	20.6	27.8	64.7	3.53
62	48	20.4	28.2	65.9	3.6
64	47.6	20.5	28.2	65.7	3.73
66	48.2	20.8	28.4	66	3.9
68	47.3	20.6	28.3	65.7	3.93
70	47.4	20.7	28.5	66.2	4.03
72	48	20.7	28.6	66.6	4.13
74	47.8	20.9	28.7	66.3	4.33
76	47.6	20.7	28.9	66.9	4.33
78	48.4	21.2	29.3	67.4	4.43
80	47.8	20.9	29.1	67	4.4
82	48	20.8	29.1	67.1	4.46
84	48.5	21.2	29.6	67.9	4.46
86	48.5	21	29.3	67.8	4.56
88	48.2	21.1	29.2	67.2	4.53
90	48.3	21.2	29.2	67.9	4.66
92	48.3	21	29.1	67.7	4.63
94	47.9	21	28.9	66.9	4.63
96	47.7	21	29.1	66.9	4.7

98	47.4	20.9	28.9	66.5	4.56
100	47.7	21	28.8	67	4.6
104	47.9	20.9	29.1	67.1	4.63
108	46.9	20.8	28.7	66	4.63
112	47.5	20.9	28.9	66.3	4.63
116	47.1	20.8	28.7	65.7	4.63
120	47.2	20.7	28.7	67.3	4.63
124	46.8	20.8	28.6	65.7	4.6
128	46.6	20.6	28	65.6	4.5
132	46.3	20.6	28.3	64.8	4.53
136	46.2	20.6	28.1	64.9	4.43
140	46.1	20.3	27.8	64.5	4.36
144	45.3	20.2	27.7	63.8	4.33
148	44.7	20.1	27.7	63	4.26
152	44.8	20.1	27.3	63	4.26
156	44.7	20	27.3	62.5	4.2
160	44.7	20	27.2	62.5	4.23
164	44.2	19.7	27	61.9	4.1
168	43.5	19.6	26.7	60.9	4.03
172	44	19.6	26.6	61.4	4.03
176	43.7	19.5	26.5	61.2	4
180	42.8	19.4	26.2	60.2	3.93
184	43.2	19.4	26.3	60.1	3.93
188	42.5	19.3	26	59.2	3.86
192	42.2	19	25.6	58.8	3.76
196	42.1	19.1	25.5	58.6	3.76
200	41.5	18.7	25.2	57.7	3.7
204	41.1	18.6	25	57.3	3.66
208	41	18.5	25	56.8	3.63
212	40.9	18.4	24.8	56.7	3.56
216	40.4	18.3	24.5	56.4	3.5
220	39.7	18.2	24.2	55.6	3.46
224	39.7	18.1	24	55.3	3.43
228	39.4	17.9	23.9	54.6	3.36
232	38.9	17.7	23.5	53.8	3.3
236	38.7	17.5	23.2	53.6	3.24
240	38.4	17.5	23.4	53.3	3.25
244	38.4	17.3	23.2	52.9	3.19
248	37.7	17	22.8	52	3.15
252	37.6	16.9	22.5	51.9	3.12
256	37.4	16.9	22.5	51.7	3.09
260	37.1	16.9	22.3	51.2	3.04
264	36.9	16.8	22.1	50.9	3.01

TABLE VI. Partial dissociative ionization cross sections for MMH; masses 14–18.

E (eV)	σ (10^{-18} cm^2)				
	18 amu	17 amu	16 amu	15 amu	14 amu
16					
18	11.2	3.79	0.611	1.35	
20	16.7	5.16	0.904	1.84	0.0325
22	21.3	6.76	1.31	2.68	0.107
24	23.9	7.59	2.02	3.31	0.235
26	27	8.75	2.37	3.99	0.417
28	29.3	10.1	2.91	4.83	0.657
30	32.2	10.8	3.26	5.6	0.963
32	34.3	11.7	3.9	6.17	1.25
34	35.7	12.5	4.29	6.88	1.71
36	36.7	13.4	4.49	7.33	2.02
38	37.3	13.2	5.03	7.52	2.32
40	37.5	13.6	5.3	7.95	2.49
42	37.5	13.4	5.38	8.09	2.75
44	37.7	13.6	5.65	8.17	2.89
46	37.5	13.8	5.76	8.63	3.03
48	37.8	14	5.93	8.9	3.15
50	37.5	13.9	5.92	8.84	3.41
52	36.4	14.1	5.97	8.68	3.42
54	37.3	14	6.36	9.12	3.62
56	36.7	13.8	6.45	9.09	3.65
58	36.6	13.9	6.52	9.33	3.72
60	36.8	14.1	6.46	9.1	3.92
62	36	14	6.36	9.13	3.94
64	36.5	14.1	6.62	9.34	4.03
66	36.9	14	6.72	9.42	4.16
68	36.3	14.1	6.79	9.44	4.2
70	36.6	14.2	6.79	9.63	4.27
72	36.6	14.1	6.88	9.54	4.32
74	37	14.2	7.06	9.78	4.44
76	36.6	14	6.95	9.63	4.42
78	37.3	14.4	7.12	9.84	4.52
80	36.8	14.3	7.06	9.7	4.54
82	37.4	14.4	7.15	9.86	4.64
84	37.1	14.4	7.16	9.84	4.58
86	37.2	14.3	7.15	9.81	4.64
88	37	14.5	7.09	9.76	4.6
90	37.5	14.6	7.23	10.1	4.68
92	37.4	14.4	7.17	9.94	4.72
94	37.2	14.3	7.13	9.92	4.66
96	37.1	14.3	7.04	9.75	4.69

98	36.5	14.1	6.96	9.63	4.64
100	36.7	14.4	6.96	9.73	4.69
104	37.1	14.4	7.08	9.73	4.78
108	36.9	14.4	6.95	9.55	4.72
112	36.9	14.2	7.16	9.76	4.72
116	36.8	14.1	7.1	9.74	4.66
120	36.9	14.5	7.01	9.65	4.66
124	37	14.4	7.04	9.63	4.7
128	36.5	14.3	6.91	9.55	4.58
132	36.6	14.2	6.88	9.52	4.6
136	36.3	14.1	6.88	9.54	4.53
140	36.3	14.2	6.79	9.45	4.51
144	36.2	14.1	6.7	9.38	4.51
148	35.5	13.9	6.58	9.23	4.37
152	35.6	13.8	6.6	9.26	4.38
156	35.5	13.6	6.51	9.14	4.32
160	35.6	13.9	6.54	9.1	4.31
164	35.3	13.9	6.46	9.06	4.24
168	34.6	13.6	6.36	8.92	4.18
172	35	13.8	6.38	8.86	4.19
176	34.9	13.6	6.33	8.84	4.18
180	34.3	13.5	6.23	8.84	4.09
184	34.6	13.5	6.28	8.74	4.13
188	34	13.4	6.12	8.53	4.01
192	33.8	13.2	6.02	8.51	3.97
196	33.7	13.1	6.11	8.61	3.92
200	33.4	13.1	5.95	8.47	3.86
204	33.2	12.9	5.94	8.36	3.81
208	33.1	12.7	5.87	8.26	3.82
212	32.6	12.7	5.76	8.17	3.74
216	32.5	12.7	5.68	8.02	3.7
220	31.8	12.6	5.63	7.91	3.57
224	31.8	12.5	5.55	7.82	3.58
228	31.5	12.4	5.56	7.88	3.54
232	31.1	12.1	5.34	7.69	3.45
236	30.9	12.1	5.39	7.6	3.43
240	30.8	12.1	5.36	7.62	3.41
244	30.6	12	5.32	7.55	3.38
248	30.2	11.8	5.27	7.45	3.31
252	30.1	11.7	5.11	7.37	3.26
256	29.9	11.7	5.12	7.31	3.24
260	29.5	11.6	5.06	7.09	3.18
264	29.4	11.5	5	7.14	3.19

TABLE VII. Partial dissociative ionization cross sections for MMH; masses 1, 12, 13, and doubly-charged 45 ion.

E (eV)	σ (10^{-18} cm^2)			
	CH^+	C^+	H^+	(45 amu)$^+$
16				
18				
20				
22				
24			0.0104	
26			0.0319	
28			0.0432	
30	0.0613		0.14	
32	0.117		0.21	
34	0.175		0.262	
36	0.301		0.343	
38	0.441		0.414	
40	0.513		0.514	0.0447
42	0.598		0.594	0.096
44	0.696	0.026	0.672	0.112
46	0.835	0.067	0.747	0.159
48	0.912	0.0805	0.829	0.15
50	0.96	0.12	0.917	0.164
52	1	0.182	0.965	0.211
54	1.07	0.164	1.08	0.248
56	1.16	0.192	1.11	0.233
58	1.19	0.235	1.21	0.297
60	1.3	0.306	1.32	0.319
62	1.39	0.327	1.28	0.33
64	1.45	0.334	1.39	0.4
66	1.52	0.395	1.45	0.385
68	1.54	0.403	1.47	0.414
70	1.6	0.436	1.58	0.428
72	1.67	0.449	1.64	0.453
74	1.72	0.496	1.68	0.456
76	1.76	0.526	1.73	0.462
78	1.89	0.581	1.8	0.463
80	1.84	0.623	1.86	0.497
82	1.89	0.638	1.89	0.52
84	1.93	0.646	1.92	0.521
86	1.97	0.685	1.95	0.514
88	1.96	0.706	1.98	0.534
90	1.99	0.793	2.04	0.508
92	2.05	0.771	2.06	0.534
94	2.06	0.748	2.14	0.521
96	2.08	0.806	2.14	0.543

98	2.03	0.79	2.13	0.518
100	2.06	0.806	2.16	0.535
104	2.13	0.86	2.22	0.529
108	2.12	0.878	2.28	0.513
112	2.14	0.899	2.3	0.514
116	2.13	0.933	2.32	0.533
120	2.16	0.976	2.4	0.504
124	2.17	0.977	2.41	0.504
128	2.15	0.967	2.39	0.493
132	2.12	0.978	2.45	0.487
136	2.11	0.986	2.45	0.496
140	2.08	0.993	2.41	0.467
144	2.11	0.992	2.46	0.457
148	2.02	0.956	2.42	0.44
152	2.01	0.986	2.41	0.423
156	1.98	0.971	2.44	0.421
160	1.99	0.94	2.4	0.434
164	1.96	0.938	2.39	0.405
168	1.9	0.921	2.33	0.391
172	1.91	0.941	2.34	0.397
176	1.9	0.927	2.35	0.399
180	1.85	0.92	2.31	0.376
184	1.85	0.914	2.32	0.385
188	1.81	0.89	2.25	0.36
192	1.78	0.858	2.23	0.349
196	1.78	0.885	2.21	0.36
200	1.75	0.854	2.17	0.33
204	1.69	0.842	2.17	0.333
208	1.71	0.83	2.11	0.308
212	1.67	0.835	2.05	0.318
216	1.64	0.811	2.05	0.323
220	1.6	0.782	1.95	0.301
224	1.57	0.777	1.96	0.308
228	1.57	0.758	1.94	0.272
232	1.52	0.739	1.9	0.284
236	1.52	0.726	1.84	0.28
240	1.51	0.716	1.81	0.285
244	1.46	0.706	1.81	0.254
248	1.43	0.687	1.74	0.249
252	1.44	0.68	1.73	0.256
256	1.39	0.648	1.71	0.239
260	1.35	0.66	1.66	0.228
264	1.36	0.645	1.65	0.251

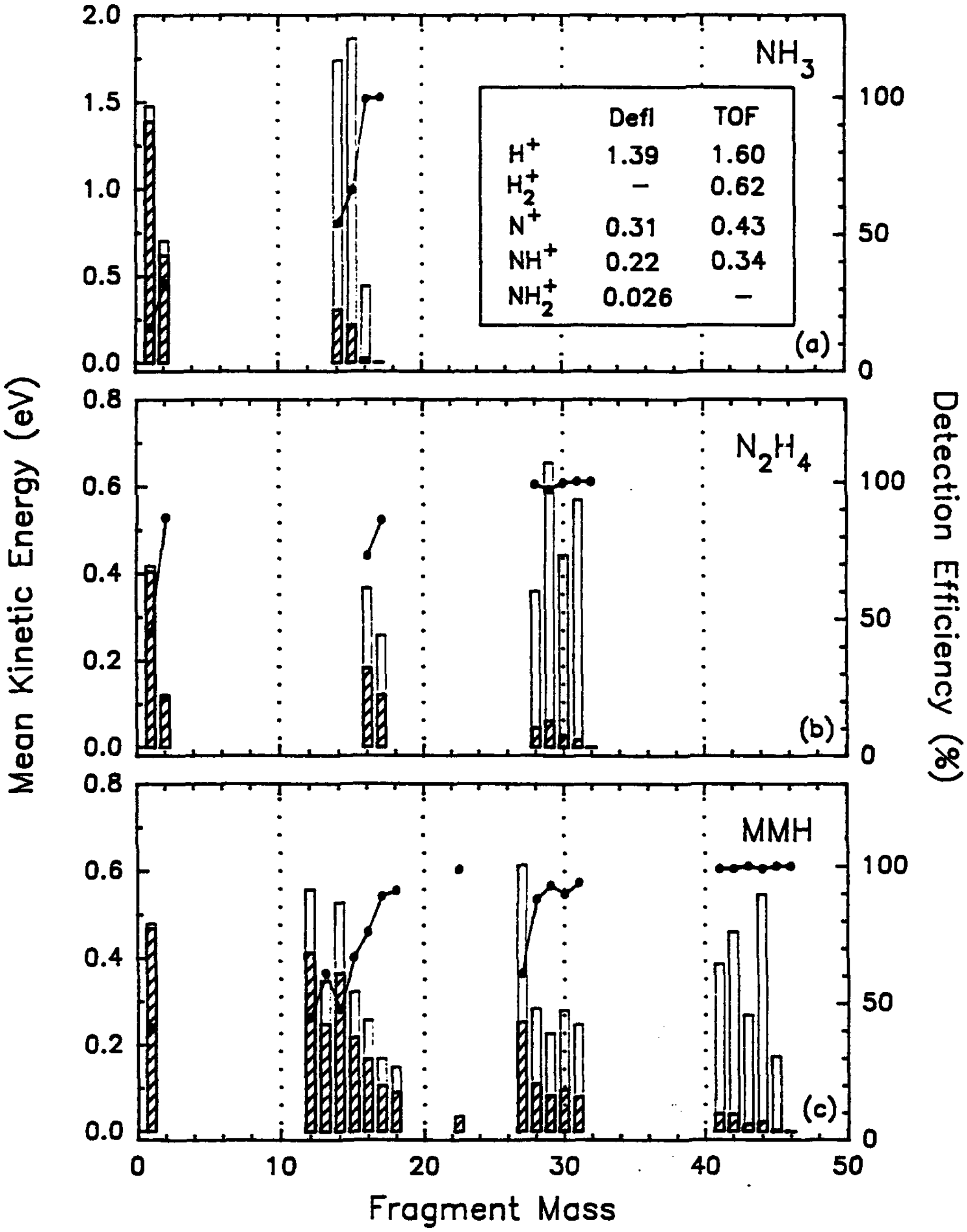

Figure 5. Mean fragment kinetic energy, $\langle \varepsilon_t \rangle$, and center-of-mass kinetic energy, $\langle \varepsilon_t \rangle_{cm}$ for 170 eV excitation are represented by the height of the cross-hatched and open bars, respectively. The latter set of values assumes two-body dissociation, although some fragments are best described by sequential multibody dissociation mechanisms, as discussed in Ref. 3. The insert compares values of $\langle \varepsilon_t \rangle$ for NH_3 ionization measured by the deflection and the TOF methods. The solid dots and lines are detection efficiencies and refer to the scale on the right-hand side.

TECHNOLOGY OPERATIONS

The Aerospace Corporation functions as an "architect-engineer" for national security programs, specializing in advanced military space systems. The Corporation's Technology Operations supports the effective and timely development and operation of national security systems through scientific research and the application of advanced technology. Vital to the success of the Corporation is the technical staff's wide-ranging expertise and its ability to stay abreast of new technological developments and program support issues associated with rapidly evolving space systems. Contributing capabilities are provided by these individual Technology Centers:

Electronics Technology Center: Microelectronics, solid-state device physics, VLSI reliability, compound semiconductors, radiation hardening, data storage technologies, infrared detector devices and testing; electro-optics, quantum electronics, solid-state lasers, optical propagation and communications; cw and pulsed chemical laser development, optical resonators, beam control, atmospheric propagation, and laser effects and countermeasures; atomic frequency standards, applied laser spectroscopy, laser chemistry, laser optoelectronics, phase conjugation and coherent imaging, solar cell physics, battery electrochemistry, battery testing and evaluation.

Mechanics and Materials Technology Center: Evaluation and characterization of new materials: metals, alloys, ceramics, polymers and their composites, and new forms of carbon; development and analysis of thin films and deposition techniques; nondestructive evaluation, component failure analysis and reliability; fracture mechanics and stress corrosion; development and evaluation of hardened components; analysis and evaluation of materials at cryogenic and elevated temperatures; launch vehicle and reentry fluid mechanics, heat transfer and flight dynamics; chemical and electric propulsion; spacecraft structural mechanics, spacecraft survivability and vulnerability assessment; contamination, thermal and structural control; high temperature thermomechanics, gas kinetics and radiation; lubrication and surface phenomena.

Space and Environment Technology Center: Magnetospheric, auroral and cosmic ray physics, wave-particle interactions, magnetospheric plasma waves; atmospheric and ionospheric physics, density and composition of the upper atmosphere, remote sensing using atmospheric radiation; solar physics, infrared astronomy, infrared signature analysis; effects of solar activity, magnetic storms and nuclear explosions on the earth's atmosphere, ionosphere and magnetosphere; effects of electromagnetic and particulate radiations on space systems; space instrumentation; propellant chemistry, chemical dynamics, environmental chemistry, trace detection; atmospheric chemical reactions, atmospheric optics, light scattering, state-specific chemical reactions and radiative signatures of missile plumes, and sensor out-of-field-of-view rejection.